

CLAIMS

What is claimed is:

1. A light source apparatus, comprising:

at least a first reflecting device having first and second focal points;

5 at least a first arc lamp having a first arc located at about the first focal point of the first reflecting device, the first arc lamp producing first light rays;

a compound parabolic concentrator (CPC) having input and output ends, the input end located at about the second focal point of the first reflecting device to receive the first light rays at the input end over a wide range of acceptance
10 angles and emit the first light rays from the output end at a substantially smaller exit angle; and

an optical integrator having an input aperture positioned to receive the first light rays from the output end of the CPC, and an output aperture from which the first light rays exit with a substantially uniform brightness.

15 2. The apparatus of claim 1, further including a first substantially spherical reflector positioned adjacent to the first arc lamp to receive a portion of the first light rays and reflect them back through the first arc.

3. The apparatus of claim 2, in which the first substantially spherical reflector includes a mirror coating applied to a portion of the first arc lamp.

20 4. The apparatus of claim 1, in which the first reflecting device includes a selected one of a free-form reflector, a double-ellipsoid reflector, and a double-paraboloid reflector.

5. The apparatus of claim 1, in which the first light rays exit the CPC with an étendue less than about $7 \text{ mm}^2 \cdot \text{sr}$.

6. The apparatus of claim 1, in which the optical integrator comprises a glass rod integrator.

5 7. The apparatus of claim 6, in which the glass rod integrator is tapered such that the cross-sectional area of the input end is less than the cross sectional area of the output end.

8. The apparatus of claim 1, further comprising:

a second reflecting device having first and second focal points, the
10 second reflecting device positioned such that the second focal points of the first and second reflecting devices are substantially coincident;

a second arc lamp having a second arc located at about the first focal point of the second reflecting device, the second arc lamp producing second light rays, the CPC input end being located at about the second focal point of the second
15 reflecting device, receives the second light rays at the input end over a wide range of acceptance angles and emits the second light rays from the output end at a substantially smaller exit angle; and

the optical integrator input aperture positioned to receive the second light rays from the output end of the CPC, and emit the second light rays from the
20 output aperture with a substantially uniform brightness.

9. The apparatus of claim 8, in which the first and second reflecting devices include a selected one of a free-form reflector, a double-ellipsoid reflector, and a double-paraboloid reflector.

10. The apparatus of claim 8, in which the first and second reflectors are relatively positioned such that a pair of imaginary lines extending from the coincident second focal points to the first focal points form about a 90° angle.

11. The apparatus of claim 8, in which the light rays enter the CPC
5 with ray angles of up to about 90° and exit the CPC with ray angles of about 30° or less.

12. The apparatus of claim 8, in which the ratio of the integrator input area to the CPC output area is about 5:1.

13. The apparatus of claim 8, in which the optical integrator
10 comprises a glass rod integrator.

14. The apparatus of claim 13, in which the glass rod integrator is tapered such that the cross-sectional area of the input end is less than the cross sectional area of the output end.

15. The apparatus of claim 8, in which the optical integrator
15 comprises a double flyseye lens integrator.

16. A projection system, comprising:

an illumination system comprising

at least a first reflecting device having first and second focal points;

at least a first arc lamp having a first arc located at about the first

20 focal point of the first reflecting device, the first arc lamp producing first light rays;

a compound parabolic concentrator (CPC) having input and output ends, the input end located at about the second focal point of

the first reflecting device to receive the first light rays at the input end over a wide range of acceptance angles and emitting the first light rays from the output end at a substantially smaller exit angle; and

5 an optical integrator having an input aperture positioned to receive the first light rays from the output end of the CPC, and an output aperture from which the first light rays exit with a substantially uniform brightness;

a reflective light valve optical arrangement optically coupled to
10 illumination system; and

a projection lens optically coupled to reflective light valve optical arrangement.

17. The projection system of claim 16, in which the reflective light valve optical arrangement comprises liquid crystal on silicon (LCOS) light valves.

15 18. The projection system of claim 16, in which the reflective light valve optical arrangement comprises a frame sequential color projection display and the illumination system further includes a color wheel positioned adjacent to the optical integrator.

19. The projection system of claim 16, in which the aspect ratio of
20 the output aperture substantially matches the aspect ratio of the light valve in the reflective light valve arrangement.

20. The projection system of claim 16, in which the illumination system further comprises

a second reflecting device having first and second focal points, the second reflecting device positioned such that the second focal points of the first and second reflecting devices are substantially coincident;

5 a second arc lamp having a second arc located at about the first focal point of the second reflecting device, the second arc lamp producing second light rays, the CPC input end, being located at about the second focal point of the second reflector, receives the second light rays at the input end over a wide range of acceptance angles and emits the second light rays from the output end at a substantially smaller exit angle; and

10 the optical integrator input aperture positioned to receive the second light rays from the output end of the CPC, and emit the second light rays from the output aperture with substantially uniform brightness.

21. A projection system, comprising:

15 an illumination system comprising first and second reflecting devices having

respective first and second focal points, positioned such that the second focal points of the first and second reflecting devices are substantially coincident;

first and second arc lamps associated respectively with reflecting

20 devices for producing respective first and second light rays; and

each arc lamp having an arc located at about the first focal point of the corresponding reflecting device;

a reflective light valve optical arrangement optically coupled to illumination system; and

a projection lens optically coupled to reflective light valve optical arrangement.

5 22. The projection system of claim 21, in which the illumination system further comprises a compound parabolic concentrator (CPC) having input and output ends, the input end located at about the coincident second focal points of the first and second reflecting devices to receive the first and second light rays over a wide range of acceptance angles and emit the first and second light rays from the
10 output end at a substantially smaller exit angle.

23. The projection system of claim 21, in which the reflective light valve optical arrangement comprises a LCOS light valve.

24. The projection system of claim 21, in which the reflective light valve optical arrangement comprises a frame sequential color projection display and
15 the illumination system further includes a color wheel positioned adjacent to the optical integrator.

25. A method for providing illumination, comprising:
generating light rays from at least a first arc lamp having a first arc;
reflecting said light rays with at least a first reflecting device having a
20 first and second focal points, the first reflecting device being positioned with the first focal point substantially coincident with the first arc of the first arc lamp;
positioning a compound parabolic concentrator (CPC) having an input and output end, such that the said input end is located at about the second focal

point of the first reflecting device, and said CPC receiving said light rays at the input end over a wide range of acceptance angles and emitting said light rays from the output end at a substantially smaller exit angle; and

positioning an optical integrator having an input and output aperture, to
5 receive the light rays, exiting the CPC output end, at the input aperture and emit the received light rays at the output aperture with a substantially uniform brightness.

26. The method of claim 25, further including positioning a first substantially spherical reflector adjacent to the first arc lamp to reflect a portion of the light rays back through the first arc.

10 27. The method of claim 25, in which said reflecting with at least a first reflecting device comprises reflecting the light rays employing a selected one of a free-form reflector, a double-ellipsoid reflector, and a double-paraboloid reflector.

28. The method of claim 25, further comprising:
positioning a second reflecting device having first and second focal
15 points, such that the second focal points of the first and second reflecting devices are substantially coincident;

generating second light rays from a second arc lamp having a second arc located at about the first focal point of the second reflecting device; and

positioning the CPC input end at about the second focal point of the
20 second reflector, such that the CPC receives the second light rays at the input end over a wide range of acceptance angles and emits the second light rays from the output end at a substantially smaller exit angle.

29. The method of claim 28, in which said reflecting with first and second reflecting devices comprise reflecting the light rays employing selected one of a free-form reflector, a double-ellipsoid reflector, and a double-paraboloid reflector.

5 30. A light source apparatus, comprising:
first and second reflecting devices having respective first and second focal points, positioned such that the second focal points are substantially coincident; and

first and second arc lamps associated respectively with the first and
10 second reflecting devices for producing respective first and second light rays, each arc lamp having an arc located at about the first focal point of the respective first and second reflecting devices.

31. The apparatus of claim 30, further comprising a compound parabolic concentrator (CPC) having input and output ends, the input end located at
15 about the second focal point of the first and second reflecting devices to receive the first and second light rays over a wide range of acceptance angles and emit the first and second light rays from the output end at a substantially smaller exit angle.

32. The apparatus of claim 31, in which the first and second light rays exit the CPC with an étendue less than about $7 \text{ mm}^2 \cdot \text{sr}$.

20 33. The apparatus of claim 31, in which the light rays enter the CPC with ray angles of up to about 90° and exit the CPC with ray angles of about 30° or less.

34. The apparatus of claim 30, further including first and second substantially spherical reflectors, positioned adjacent to respective arc lamps, to receive a portion of the respective light rays and reflect them back through the respective arcs.

5 35. The apparatus of claim 34, in which the first and second substantially spherical reflectors include a mirror coating applied to a portion of the arc lamps.

36. The apparatus of claim 30, in which the first and second reflecting devices include a selected one of a free-form reflector, a double-ellipsoid reflector, and a double-paraboloid reflector.

37. A method for providing illumination, comprising:
positioning first and second arc lamps, such that their respective arcs are located at about first focal points of respective first and second reflecting devices, which are positioned such that their second focal points are substantially coincident; and

15 generating first and second light rays from the first and second arc lamps for the first and second reflecting devices.

38. The method of claim 37, further comprising positioning a compound parabolic concentrator (CPC) having an input and output end, such that the input end is located at about the second focal point of the first and second reflecting devices, and said CPC receiving said light rays at the input end over a wide range of acceptance angles and emitting said light rays from the output end at a substantially smaller exit angle.

39. A system comprising:
a video unit with an output video signal; and
a projection system, coupled to video unit, to receive video signal and
project video, said projection system comprising

5 an illumination system comprising first and second reflecting devices
having respective first and second focal points, positioned such that
the second focal points are substantially coincident, first and
second arc lamps associated respectively with reflecting devices for
producing respective first and second light rays, each arc lamp
10 having an arc located at about the first focal point of the
corresponding reflecting device;
a reflective light valve optical arrangement optically coupled to
illumination system; and
a projection lens optically connected to reflective light valve optical
15 arrangement.

40. The system of claim 39, in which video unit is a selected one of
a DVD, video camera, and set-top box.

41. The system of claim 39, in which illumination system further
comprises a CPC having input and output ends, the input end located at about the
20 second focal point of the reflecting devices, said input end receiving light rays over a
wide range of acceptance angles and emitting light rays from the output end at a
substantially smaller exit angle; and

an optical integrator having an input aperture positioned to receive the light rays from the output end of the CPC, and an output aperture from which the light rays exit with a substantially uniform brightness.

42. The system of claim 39, in which the reflective light valve optical
5 arrangement comprises a LCOS light valve.